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Design Guidelines for Flood Damage Reduction

Federal Emergency Management Agency

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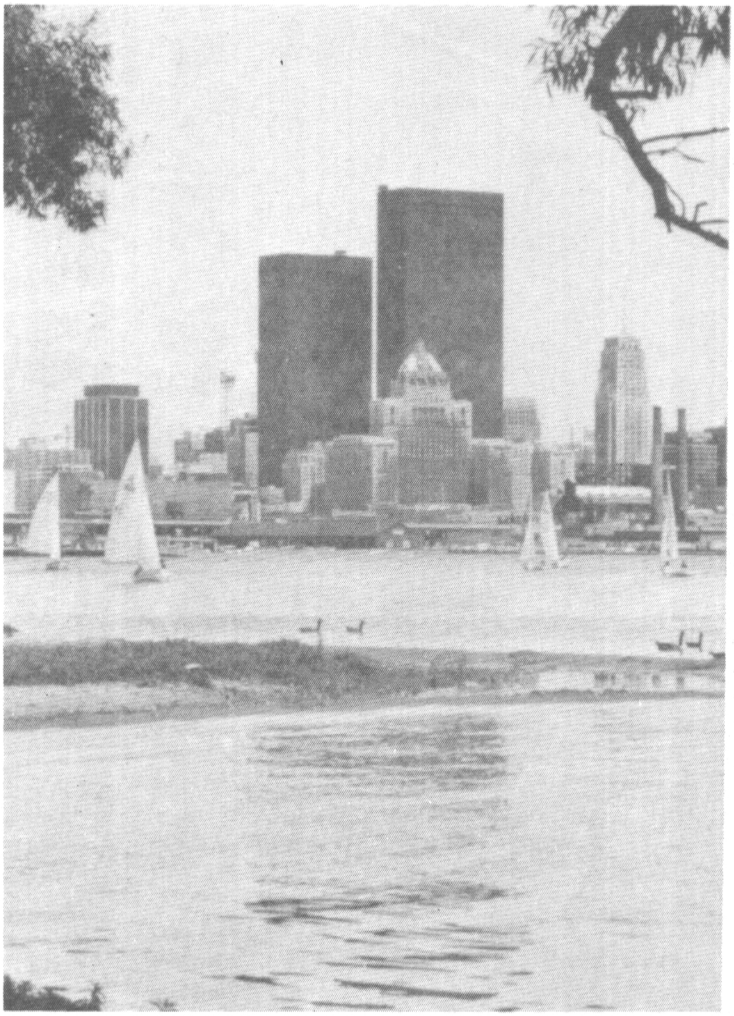
Preface

The Federal Emergency Management Agency, is charged with implementing the National Flood Insurance Act of 1968. Under this act FEMA is responsible for administering the National Flood Insurance Program and sponsoring other activities intended to reduce losses attributable to flooding. In pursuit of the latter goal FEMA has sought to:

- Encourage wise land-use and watershed management practices.
- Encourage better integration of natural and social systems.
- Encourage appropriate design and construction practices in flood-prone areas.

This manual has been prepared by the AIA Research Corporation as a special study for the FEMA to assist in meeting these objectives. The manual focuses on the need for improved building and site design in flood-prone areas—not, however, in isolation from effective floodplain management, which must accompany improved design if flood losses are to be reduced significantly.

Reduction of flood losses depends on damage mitigation activities by a variety of those involved in the use of our water and land resources. This responsibility falls to a large extent on those who design the built environment, since damage to buildings and their contents is the most common source of monetary loss in a flood disaster. For these designers to effectively contribute to flood damage reduction, they need specific information on the causes of flood damage and on ways to decrease losses through the design process. This manual has been prepared to provide that information.


Ron Vickers Ltd., AIA Journal

Chapter I

Introduction

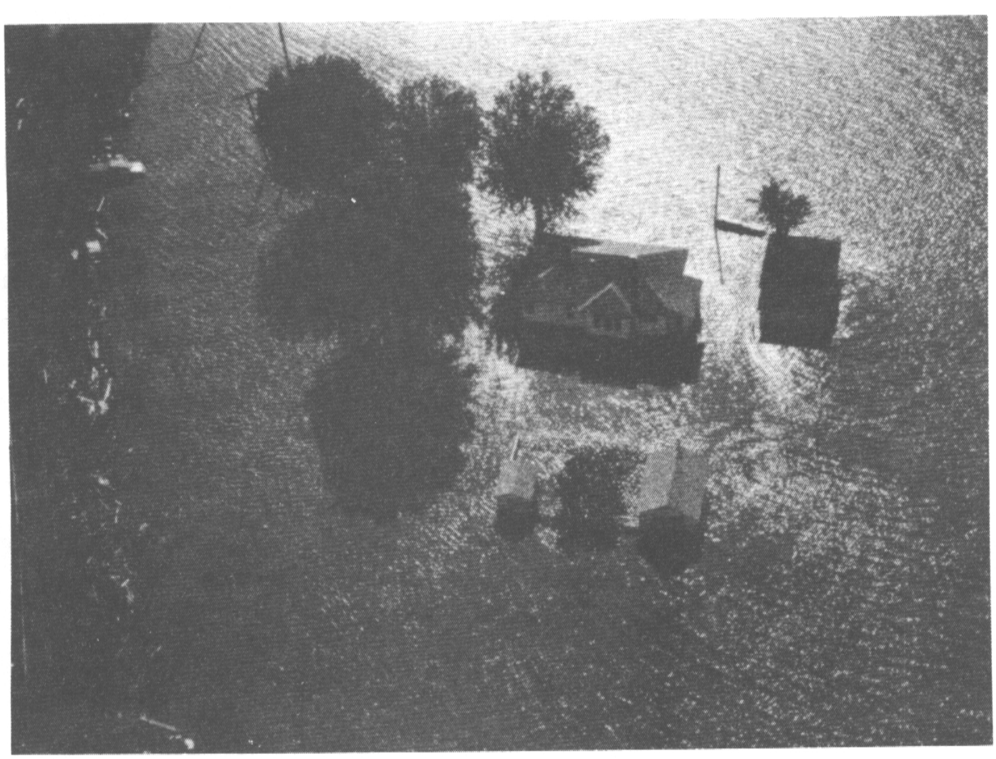
The process of human development has been linked to oceans and rivers since the earliest phases of western civilization. Access to water has been essential for sanitation, transportation, energy, economic development, defense, recreation, and social amenity. The preeminence of these factors has fluctuated throughout history, but the reliance on water has continued.

Parallel to cultural evolution and its need for access to water has been the development of large segments of the built environment along seacoasts and riverbanks, with human settlement patterns having taken both social and economic advantage of the natural environment. However, this pattern has also led to a conflict between natural systems and social systems: The need for direct access to water has resulted in human occupation of low-lying areas that are subject to periodic inundation.

PARNG Photo

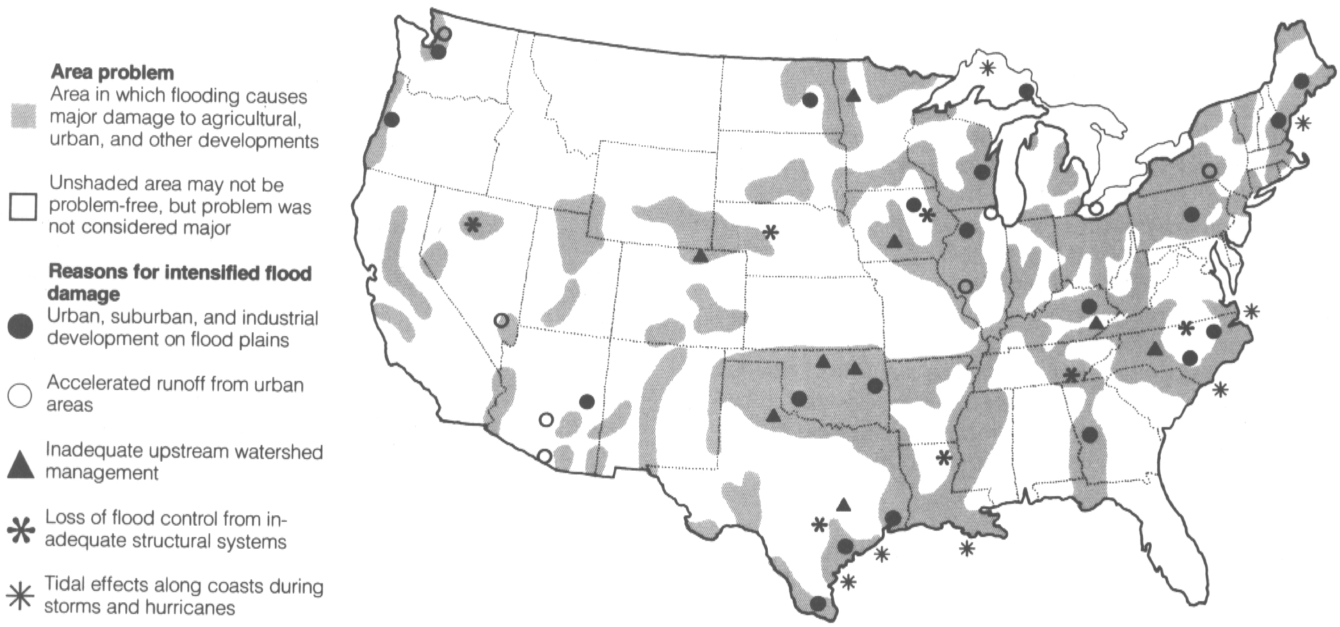
Flood Damage

Flooding occurs naturally as one part of the earth's hydrologic system. It is when this natural event is combined with the human tendency to live at the water's edge that the interaction of natural and social environments produces the potential for disaster. Unfortunately, this potential has been realized repeatedly throughout history, and the conflict is not yet resolved; losses due to flooding continue to increase.



Department of Housing and Urban Development

Cultural evolution led to the location of large segments of the built environment adjacent to water. This pattern can lead to disaster when flooding occurs.



Flooding Problems in the United States. This map shows the areas of the country in which flood damage is most prevalent and identifies some of the causes of flooding in the respective areas.

In the United States, approximately 160 million acres of land are in floodplains, with more than 6 million dwellings and a large number of nonresidential buildings located there. Periodic inundation of these floodplains is responsible for more damage to the built environment than any other type of natural disaster. The following figures indicate the seriousness of the problem.

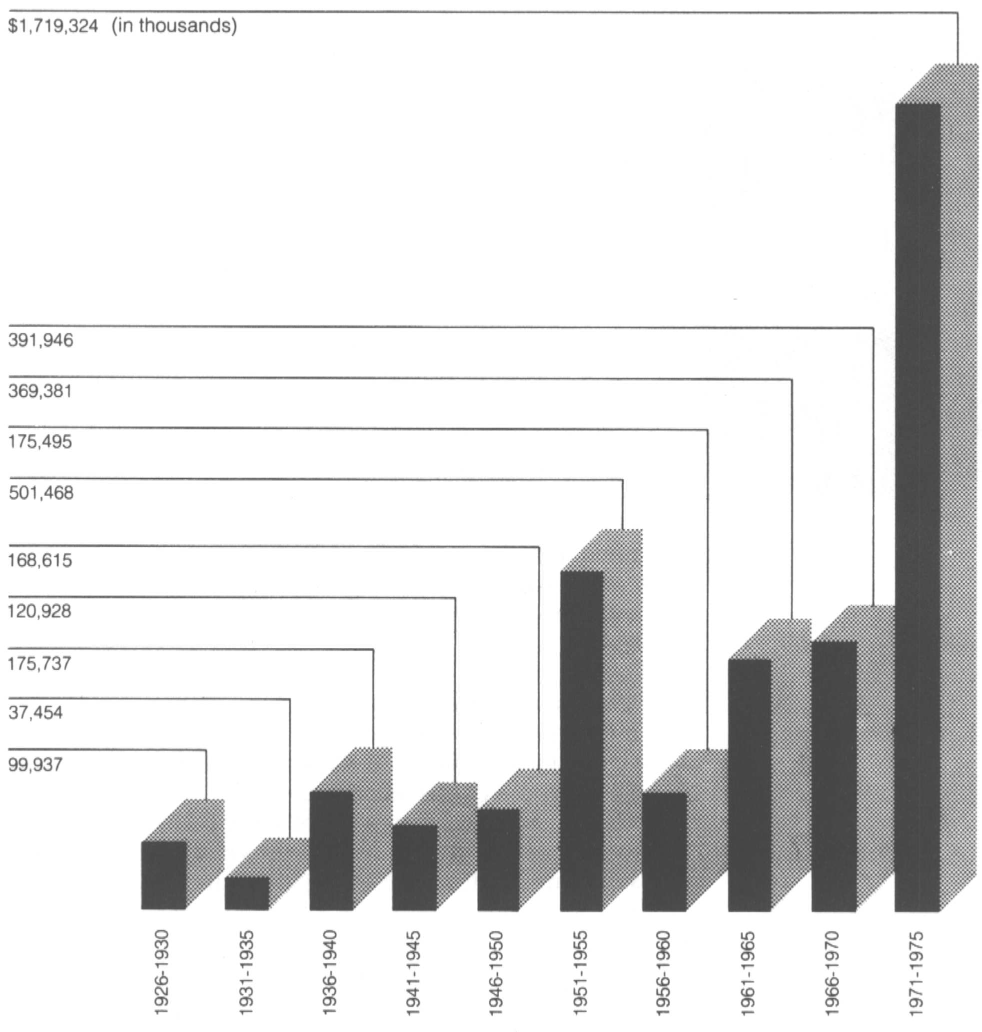
- In the six-year period between 1973 and 1979, there occurred 193 major natural disasters and 77 Presidentially declared emergencies; of these approximately 80 percent involved flooding.
- In 1978, the total flood damage—both economic and social—has been estimated to have been $3.8 billion.
- The estimated average property loss in the 1970's was over $1.7 billion annually.
- In 1978, 17 states suffered flood damage serious enough to be declared disaster areas.
- In 1979, Hurricane Frederic alone caused $1.8 billion in damages, much of it from flooding.

Response to Flooding

There have been many attempts to moderate the impact of flooding, with modern efforts dominated by structural flood control measures devised to reduce or eliminate flooding itself or to protect areas from the effects of flooding. However, the continuing damage due to flooding and current awareness of the nature of flooding have led to a shift toward a more comprehensive range of flood damage reduction methods. Attention has turned from total reliance on dams, levees, etc., to include nonstructural measures such as land and water resource management and techniques for floodproofing individual buildings.

The reason for the expanded view of damage mitigation strategies is twofold. First is the realization that floods cannot be totally eliminated. Second is the realization that better integration of the built environment with natural forces provides an environment that is both benign and rewarding.

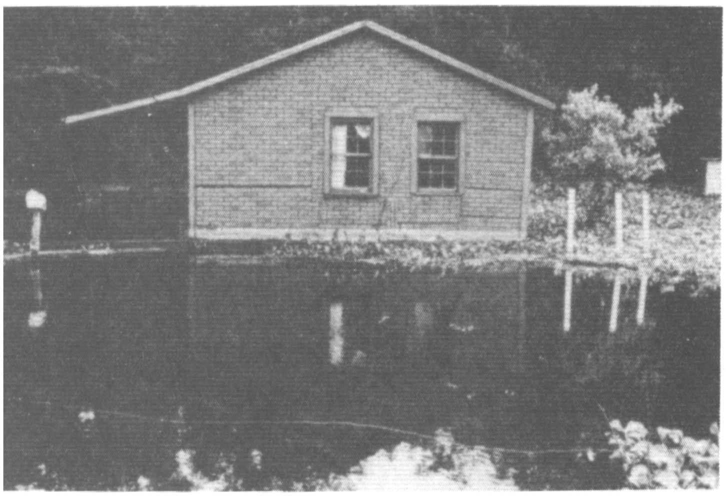
The need for a more comprehensive approach to flood damage reduction is recognized and supported by the various government agencies with a role in management of water resources and mitigation of natural disasters. Official policy of The American Institute of Architects (AIA) reflects this same awareness, as the following excerpt from the AIA's policy statement on the subject indicates.



Flood Losses. This table shows the average annual losses of property from flood in the United States, 1926-1975. The U.S. Water Resources Council, in preparing the data, concluded that the escalating flood damages resulted from continued development in floodplains and increases in the costs of making needed repairs.

Flood damage is more than dollars and cents. It affects thousands of people, causing loss of their homes, personal property, and often lives.

Department of Housing and Urban Development



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The AIA calls upon its members to exert leadership by alerting their clients to federal flood hazard boundary maps and data as to the human and material hazards and the potential environmental impacts of building in riverine floodplains, and by assisting clients in seeking alternative locations for building projects. However, when construction in riverine floodplains is undertaken, AIA calls upon its members to incorporate mitigating measures into both site development and building designs.

The premise underlying this statement is basic to this manual as well: The best way to reduce hazards in flood-prone areas is to eliminate buildings from them, thus transforming what would be human disasters into unexceptional natural events. However, such total prohibition is no more likely to be achieved than is complete control of flooding. It is inevitable that some buildings will continue to be located in flood hazard areas. This being the case, designers of the built environment are compelled to give consideration to flood hazards and ways to reduce them.

Purpose of the Manual

It is within this context that the present manual of design guidelines for flood damage reduction has evolved. The purpose of this manual is to assist designers in their task—in effect, to give them the basic information and the tools necessary to reduce the losses that continue to result from flooding. Specifically, the manual tries to meet this need by answering the following questions:

- What are flooding's inherent characteristics?
- How does flooding relate to the built environment?
- What steps have been taken to mitigate flood damage?

- What programs influence development in flood-prone areas?
- What essential information is needed to design in flood-prone areas?
- What design techniques are available to mitigate flood damage to the built environment?
- Where can the designer obtain additional information about flooding?

Organization of the Manual

In answering the above questions, the manual has been organized into three sections.

The first section, Chapters 2 and 3, provides background information on flooding to assist the designer in addressing the problems of designing in flood-prone areas. Chapter 2, **Flooding and the Built Environment,** discusses the natural characteristics of flooding and the interrelationships between flooding and the built environment. Chapter 3, **Policies, Programs, and Strategies for Flood Damage Reduction,** deals with the evolution and content of government flood-related programs and outlines general strategies for reducing flood losses.

The second section deals specifically with design issues. Chapter 4, **Design Analysis for Flood Damage Reduction,** details the range of information that is needed for pre-design analysis of projects in flood-prone areas, including a discussion of relevant regulations, hydrologic data, and physical site characteristics. The final chapter, **Design Techniques for Flood Damage Reduction,** outlines the various techniques that designers can use to mitigate the flood damage potentials identified in pre-design analysis.

Finally, the third section of the manual is a **Resource Index,** which provides additional sources of information that can be investigated by the designer when further detail is necessary. Included here are literature references on a wide range of flooding and development issues, as well as listings of key regional contact points for the variety of government agencies with an interest in flooding and development.

It is hoped that this manual proves to be a frequently used addition to the designer's reference shelf. It is intended to mark a beginning towards a more conscious inclusion of flooding issues in the routine procedures of design practice. If, beyond that, it helps the designer accept the challenge of finding creative and effective solutions to the problems of building in flood-prone areas, then both clients and the community will benefit.

American Institute of Architects Policy Statement

WHEREAS, flood plains adjoining inland rivers and coastal waters have been preferred locations for human settlements throughout history;

WHEREAS, current land use practices and increased urbanization have significantly increased human intervention within flood plain boundaries;

WHEREAS, construction in flood plains carries the risk of severe damage to such construction and its occupants and affects water quality, drainage patterns and balances between human and material systems;

WHEREAS, architects could be held liable for damages if they ignore flood plain information that is readily available, therefore, be it

RESOLVED, that architects should become involved in their local communities in order to develop wise flood plain management, regulations, and practices.

FURTHERMORE, The American Institute of Architects calls upon its members to exert leadership by alerting their clients to federal flood hazard boundary maps and data as to the human and material hazards and the potential environmental impacts of building in flood plains, and by assisting clients in seeking alternative locations for building projects. However, when construction in flood plains is undertaken architects shall incorporate mitigating measures into both site development and building designs.

Chapter 2

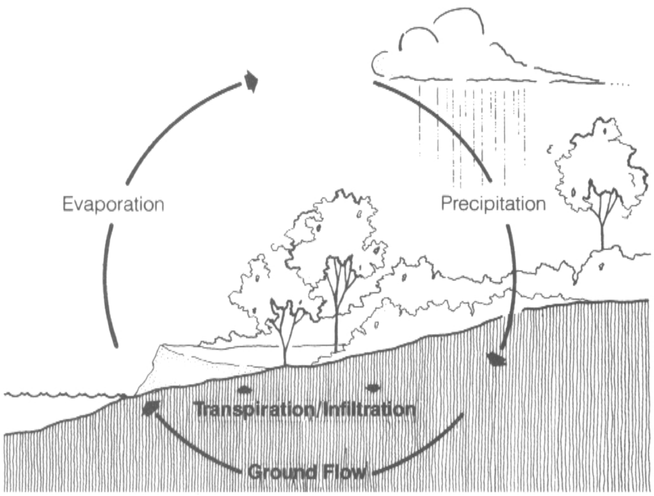
Flooding & the Built Environment

Building design does not occur in a vacuum. Rather, it is one of the interrelated elements in the larger sphere of the development process. Likewise, development is but one component of the environment as a whole. An understanding of these relationships is requisite to reducing flood damage through design of the built environment.

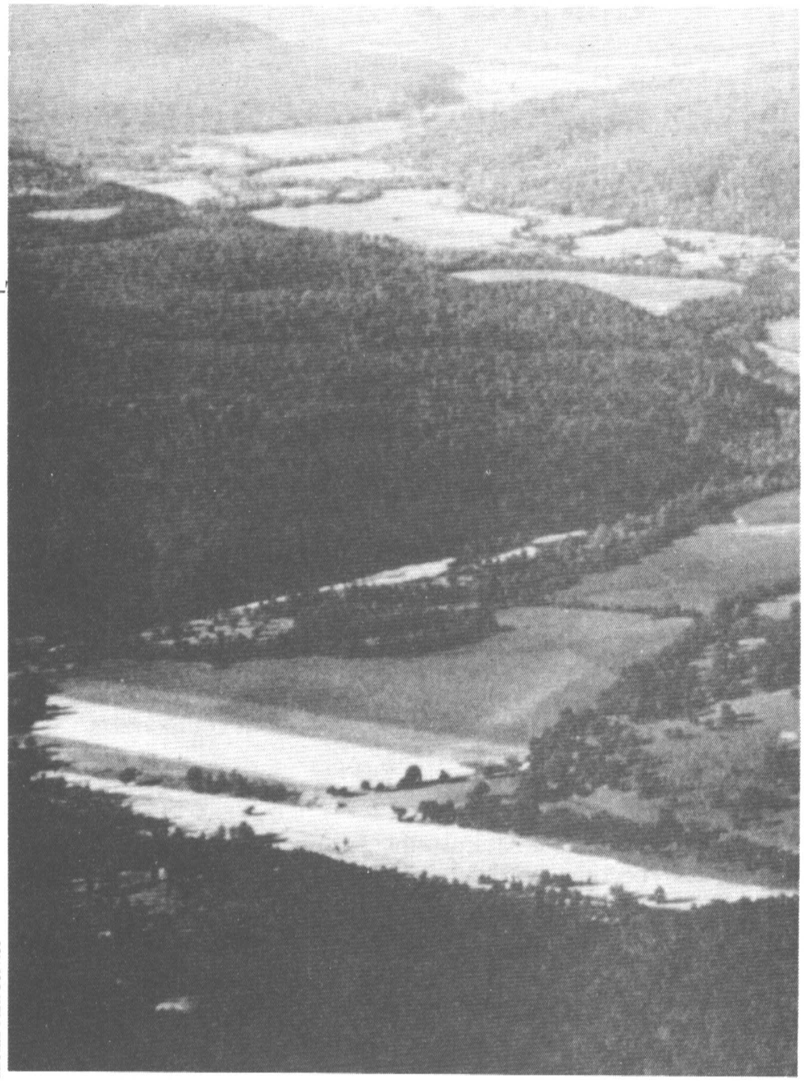
Of primary importance is the interdependence of the respective systems, natural and social. Buildings, as part of the social system, unavoidably affect and are affected by flooding, which is part of the natural system. Design in general, and design to reduce flood damage in particular, should respect this relationship and seek to achieve a balance among the various components.

The Natural System

Floods are natural—that fact must be stressed. Floods become a problem only when they coincide with human

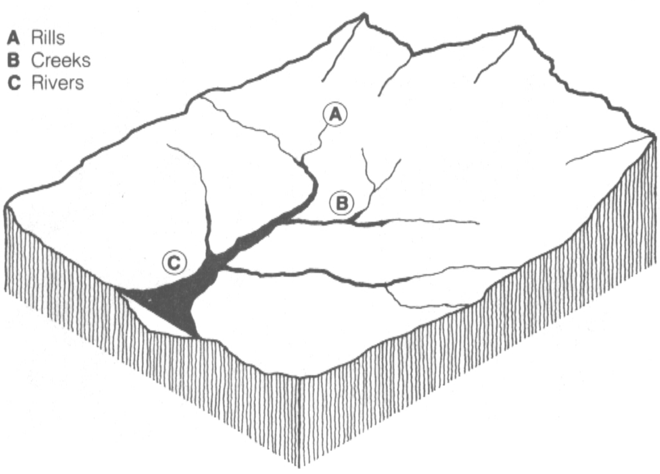


The hydrologic cycle constantly circulates water throughout the earth's environment.



National Park Service

The riverine watershed is a hierarchical drainage system that conveys water through the land-based portion of the hydrologic cycle.



habitation. To better understand this problem we look first at the natural system of which flooding is a part.

The Hydrologic Cycle

Flooding is part of the earth's natural hydrologic cycle. The cycle circulates water through a process of evaporation and transpiration, precipitation, water runoff, and stream flow. This process maintains an overall global balance between atmospheric moisture and water on the surface and in the ground. Often, however, local imbalances result in flooding.

Flooding results when the flow of water is greater than the normal carrying capacity of a stream, or where coastal waters exceed the normal high tide. This raises an important distinction between riverine and coastal flooding; though both are part of the global hydrologic system, the respective causes are dissimilar. Rivers flood when water overflows the channel because of excessive water runoff or blockage of the channel. Coastal flooding results from high water produced by storm systems or tsunamis (seismic sea waves).

Riverine Flooding

The magnitude, duration, and frequency of floods are influenced by a region's natural characteristics. One pri-

Riverine systems evolve to form distinct stream channels and floodplains. The drawings at left illustrate this gradual formation, while the photo at far left shows a well-defined channel and floodplain.

mary variable is the watershed, which is the natural drainage basin that conveys water runoff in the land-based portion of the hydrologic cycle. Water that is not absorbed by the soil and vegetation becomes surface water runoff, seeking the natural drainage lines according to local topography. These lines merge to form a hierarchical system of streams that includes rills, creeks, and rivers, each of successively larger capacity.

Streams have specific physiographic characteristics. The primary element is the stream channel, which carries the normal flow of water through the watershed system. The area of flat or gently sloping land adjacent to the channel is the floodplain. Flooding usually involves a build-up of water in the channel, followed by overflow of excessive quantities of water that inundate the floodplain. Generally, this rise in water surface elevation is quite slow in large streams and more rapid in smaller ones.

Flooding is part of the natural renewal of the earth's resources. Overflows play a positive role in the natural system by replenishing soil moisture and depositing fertile silt from the river channel onto the floodplain.

Flash Flooding. Flash flooding usually consists of a quick rise in water surface elevation, with abnormally high water velocity often creating a "wall" of water moving down the channel and floodplain. Flash floods usually

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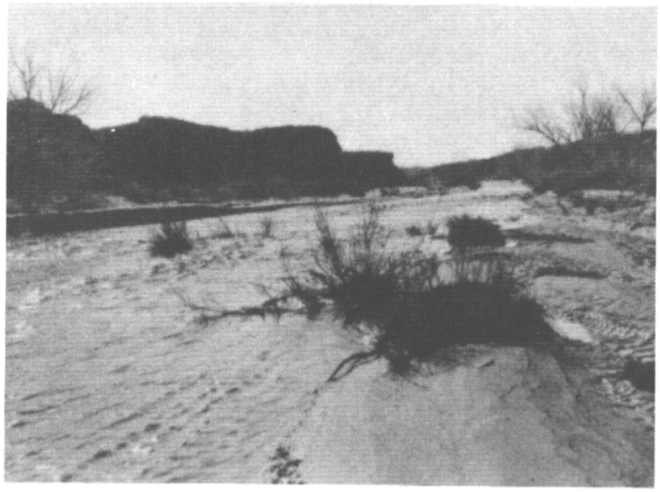


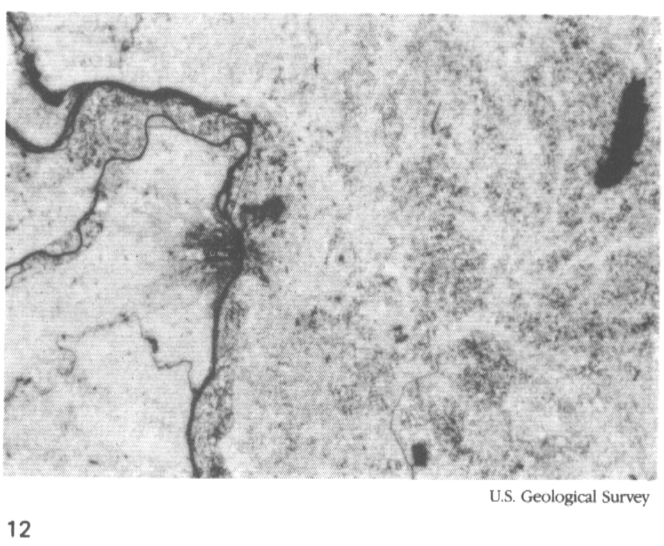
National Park Service

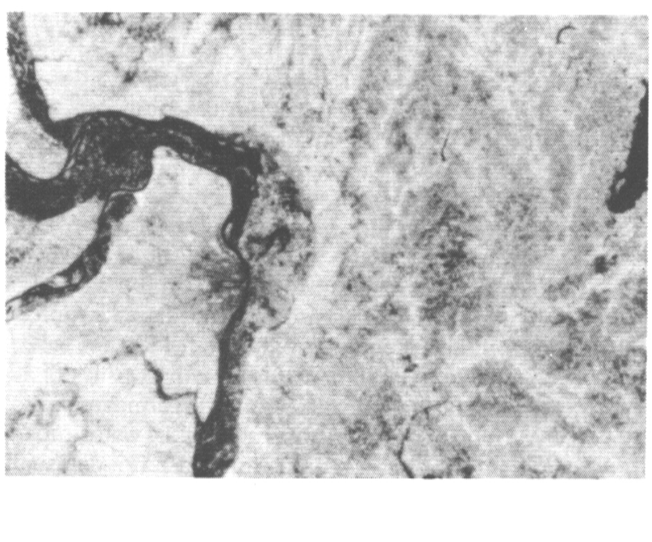
Flash flooding can occur in small, usually shallow or dry streams, such as arroyos in the southwestern part of the country.

result from some combination of intense precipitation, steep slopes, a small drainage basin, and a high proportion of impervious ground surfaces. They are evident in many parts of the country and often occur in small streams that are otherwise shallow or dry, such as arroyos.

Shallow Flooding. Shallow flooding of several types occurs commonly throughout the country. Included in this category are unconfined flows over broad, relatively low areas such as alluvial plains; intermittent flows in arid or semi-arid regions that have not developed a system of well-defined channels; minor overbank flows that remain unconfined; overland flow of runoff in dense urban areas; and flows where heavy debris deposits cause constantly shifting channels, such as in alluvial fans. These types of flooding are also referred to as sheet flow, ponding, shallow overflow, and alluvial fan flow. It is very difficult to determine shallow flooding depths, the extent of such

Aerial photographs dramatize the potential for flood damage. The picture on the left shows the normal flow of a river through an urbanized region. At right is the same area during a flood.





U.S. Geological Survey

flooding, or the direction of flow, because shallow flooding is not readily analyzed in relation to more serious channel flooding.

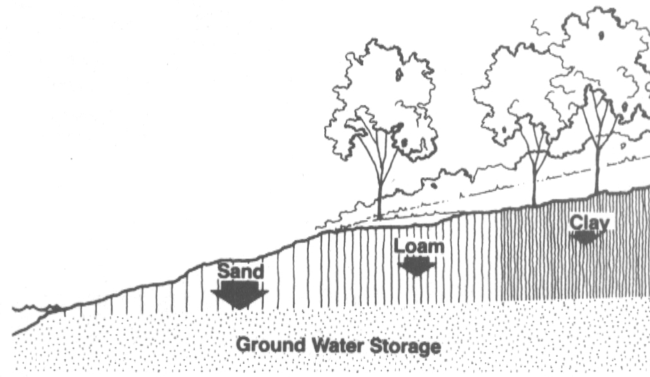
Flood Severity. Flood severity is determined first by the amount of water runoff to be conveyed through the watershed. Flooding is most likely to occur during times of heavy rainfall or snowmelt, when the amount of runoff is higher.

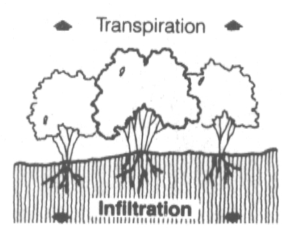
Soil characteristics, ground and surface water storage, and vegetation also influence flood levels. Soil permeability determines how much surface water can be absorbed rather than adding to runoff. Water runoff that collects in surface depressions will be released gradually into the ground and atmosphere and not contribute to flooding. Likewise, ground water that collects in cavities beneath the earth's surface helps reduce runoff and flooding. Finally, vegetation slows the rate of water runoff by holding moisture on leaves and in roots, and then releasing it to the air through evaporation and transpiration.

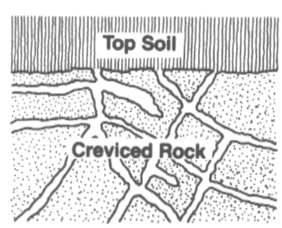
Thus, if a specific site has little permeable soil, no water storage capacity, and sparse vegetation, water either from a storm or from higher ground will flow directly across the surface of the site, adding to a build-up of water that may be in excess of the nearest stream's capacity. Obviously, the bigger this hypothetical site or region the greater the flooding impact throughout the watershed.

Coastal Flooding

Coastal flooding, on the other hand, has little to do with the movement of water through a watershed. Rather, it is due to the effects of severe ocean-based storm systems. Hurricanes, tropical storms, and extratropical storms such as "northeasters" are the principal causes, with flooding occurring when storm tides are higher than the normal







Variable soil porosity, as illustrated above, influences the degree of surface water absorption and runoff. Vegetation, left, holds water in leaves and roots, releasing it gradually through transpiration and infiltration. Water absorbed by the soil, below, is held as ground water in cavities below the water table.

U.S. Army Corps of Engineers

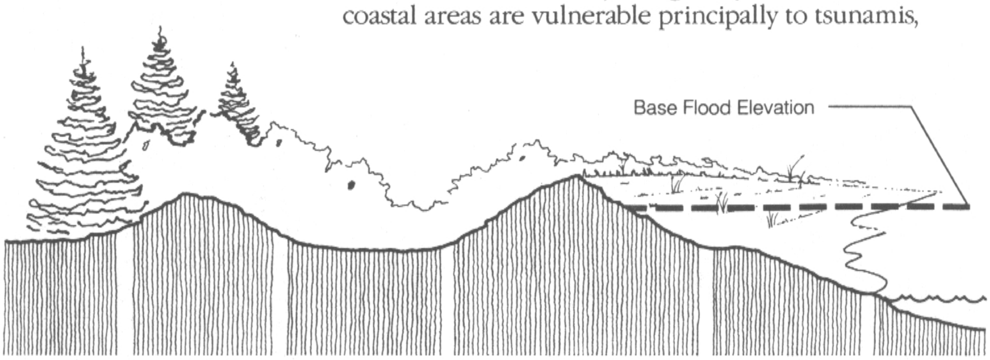
Coastal storms cause damage through the combined effects of wind, rain, wave wash, storm surges, scour, and battering by debris.

Wetland areas are frequently part of the coastal ecosystem. They can provide a reservoir for storage of flood waters and protect against storm-induced erosion.

high tide. This is known as a storm surge.

The velocity and range of coastal floods vary in part with the severity of the storm that induces them. The damaging effects of coastal flooding are caused by a combination of the higher water levels of the storm surge and the rain, winds, waves, scour, and battering by debris. The maximum intensity of a storm surge accompanies high tide, so storms that persist through several tides are the most severe.

The extent and nature of coastal flooding is also related to physiographic features of the terrain and the characteristics of the adjoining body of water. Pacific coastal areas are vulnerable principally to tsunamis,



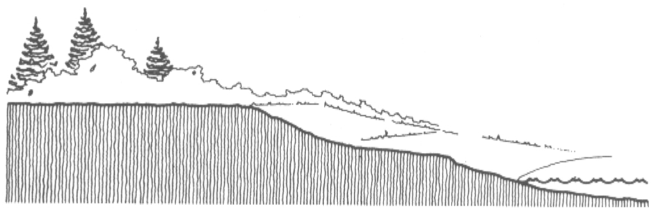
A typical coastal ecosystem consists of beach, dunes, and troughs between and behind the dunes. The beach and dunes are the more fragile components of this environment and should not be disturbed by development.

earthquakes, and other natural forces that can trigger excessive erosion, mud slides, and flash flooding. Great Lakes coastal areas are subject to erosion and severe winter storms. The Atlantic and Gulf Coasts are consistently exposed to the forces of hurricanes, lesser tropical storms, and northeasters. Each of these coastal areas suffers significant flooding, but it is the latter that has received the greatest amount of damage.

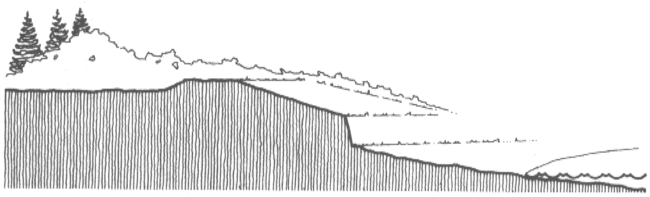
Balance of Coastal System. Most of the Atlantic and Gulf Coasts are made up of a succession of low-lying barrier islands, beaches, sand dunes, and bluffs. This collection of physiographic elements constitutes a fragile ecosystem that serves an important function in maintaining the natural environment.

A dynamic balance of natural elements occurs as the movement of sand by wind, waves, and ocean currents maintains the beach and dune system. Dunes serve to catch and hold sand, thus keeping a constant supply to replenish the natural erosion of beach sand. This coastal system helps buffer the force of storm tides and surges. Wetlands, which are often an added element in the coastal system, provide flood water storage and protect against storm-induced erosion.

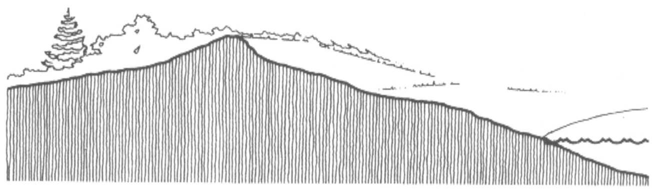
Physiographic characteristics vary along the length of the coast, and influence the type and extent of flooding. Beaches may be wide and flat, with low dunes, or they may be of medium-to-narrow width, with higher dunes and bluffs back from the water. The coast may be terraced, with height gradually increasing as the distance from the water increases. Or there may be a barrier dune or sand bar as a natural levee between water and land. These configurations will influence flooding by providing variable degrees of buffering.



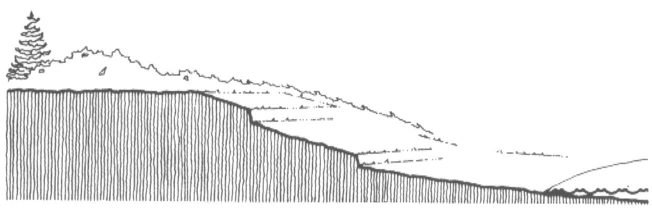
Low Dunes and Flat Beach



Low Coastal Bluff and Narrow Beach



High Dune and Wide, Sloping Beach



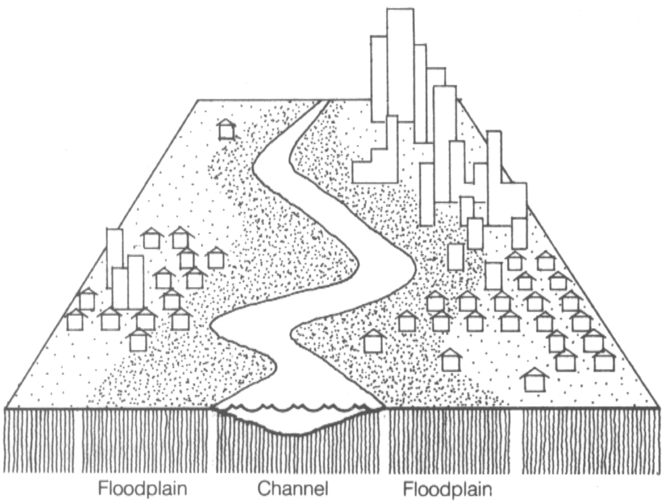
Terraced Coast

Variations in coastal topography can influence the extent of flooding because of their variable resistance to storm surges and tidal waves.

The Built Environment

As noted in the previous chapter, development along coasts and rivers is the result of a logical evolution, with human settlements benefiting both socially and economically from the natural system. The majority of this development occurs in urban areas, but is also apparent at the urban fringe, in small towns, and in rural areas. Development ranges from the single isolated building to the multi-building complex, and includes residential, commercial, and industrial building types.

However, this pattern has also led to a conflict between natural and social systems. The need and desire for direct access to water has resulted in human occupancy of low-lying areas, and this has put a large proportion of the built environment in flood-prone areas. The floodplain is transformed into a flood hazard area, and destruction of the human habitat becomes commonplace.

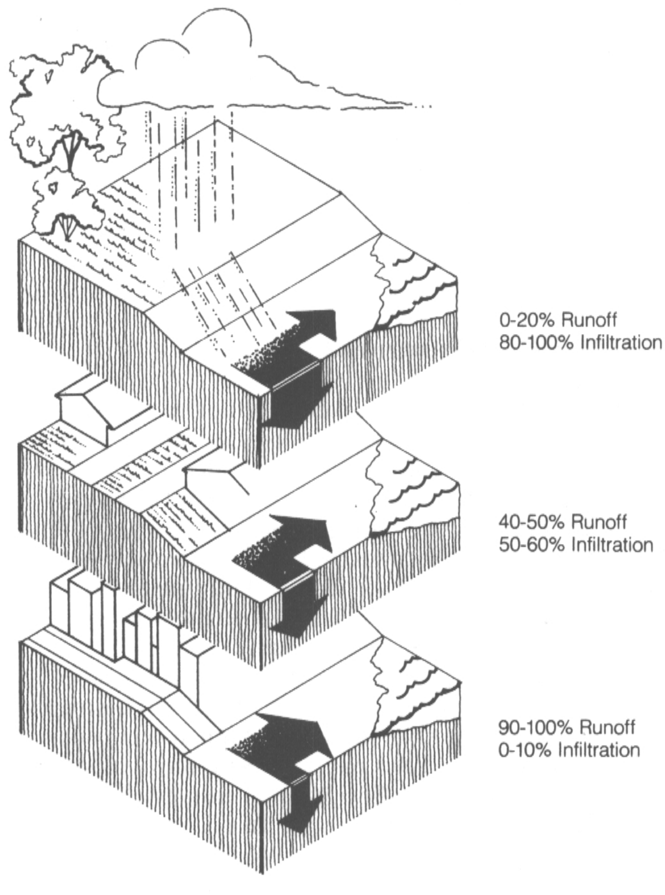


Development occurs in urban, suburban, small town, and rural settings, and buildings in many of these areas have been located on hazardous flood-prone sites.

Riverine Development

The introduction of built elements into flood-prone areas adds a range of factors, other than physiographic, that affect the degree of flooding. In riverine watersheds, development has consistently altered the natural topography, thus modifying drainage patterns and increasing storm water runoff. Development also displaces much of the natural vegetation that would otherwise absorb water, and decreases the permeability of soil by covering it with buildings or with nonporous surfaces (e.g., roads, sidewalks, and parking).

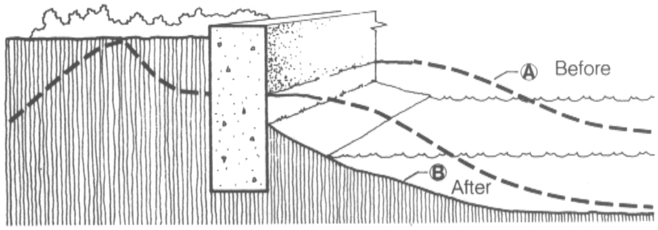
Ultimately, these development characteristics, either singly or in combination, cause a drastic increase in the amount and velocity of water runoff. Thus, during times of severe storms or heavy snowmelt the river system is quickly filled beyond its capacity and flooding results. The levels of flooding are increased not only by the abnormal runoff, but also because buildings located on the floodplain displace a volume of flood water. The more buildings on the floodplain, the greater is the displacement and the greater the level of flooding.



Development in the watershed alters natural drainage characteristics and decreases the permeability of soil, thus exacerbating the effects of flooding.

Coastal Development

In coastal areas development has similar effects because the delicate balance of shoreline elements is easily upset. The removal of beach sand and the leveling of dunes, along with the construction of seawalls, jetties, and piers, have been common practices in coastal construction. Yet, these measures weaken the shoreline's natural protection system by introducing static elements into the dynamic process that, left alone, is able to respond to constant wind and wave action. Such changes exacerbate the impacts of storm surges and high winds. Filling natural wetlands to increase developable land also eliminates such natural defenses against flooding.



Construction of seawalls alters the dynamic balance of the coastal ecosystem and causes erosion of the beach and seabed. The dotted line (A) represents the original profile with gently sloping beach and seabed. The profile after construction of the seawall (B) shows loss of beach area and steep slope of seabed.

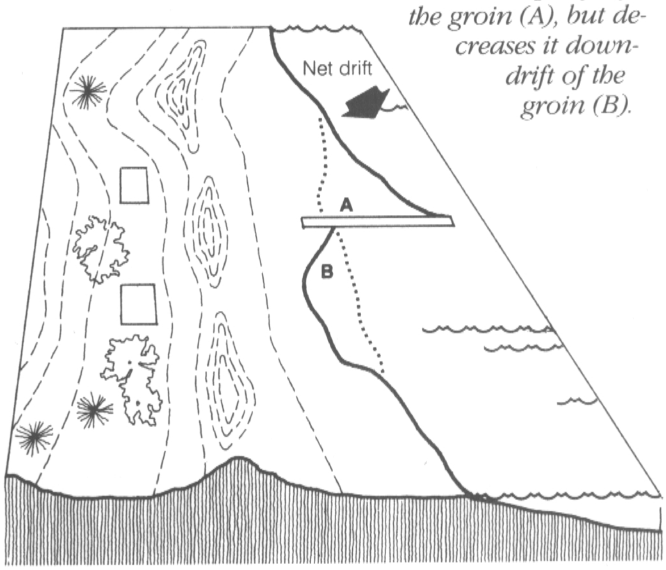
Urbanization

The effects of development on flooding are most pronounced in the urban environment. If a building and its accessories, such as sidewalks, parking lots, and access roads, can increase water runoff, then the combined effect of many buildings, streets, parking lots, and sidewalks can increase it far beyond the capacity of the watershed system. The same is true of ocean-side cities and their effect on delicate coastal ecosystems.

With the rapid expansion of cities since the late 1940's, ever-larger concentrations of land have been covered with buildings and pavement. As a result, surface drainage has been continually increased, and the capacity of the natural system to accommodate it has been exceeded repeatedly. And, the problem has not really been alleviated by flood control projects. On the contrary, flood control structures have encouraged much of the expansion onto floodplains, since these seemingly attractive building sites were thought to be protected.

Energy restrictions, economic forces, land speculation, increases in household formation, and the desire for amenities will bring continuing pressure for urban expansion. As this development occurs, people both in and out of the building process must be aware of the full costs and other effects arising from the necessary interdependence of natural and social systems.

Groins, constructed to stabilize the beach at one point, can have a reverse effect for adjacent areas. Shoreline erosion increases the beach area updrift of the groin (A), but decreases it downdrift of the groin (B).



Effects of Development

The dangers of development in floodplains take several forms. As discussed above, development can increase the severity of flooding. Also apparent is that buildings themselves, subject to the forces of flood waters, will be damaged. And, when damaged, parts of a building can break loose and act as battering rams when carried by the current of the stream or storm surge.

A less obvious danger can result from development in areas that are not subject to direct flood hazard. Virtually every site is part of a riverine watershed or coastal

David Valdez, Department of Housing and Urban Development

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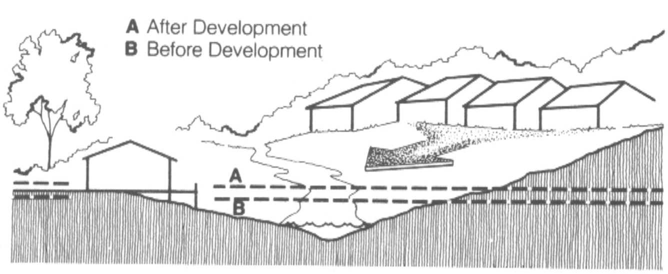
system. Even if the site itself is not likely to be flooded, development on it can have a major influence on flooding and flood damage at other locations. Any modification that increases runoff or disrupts natural protective systems will increase flooding at other locations, whether it be in the downstream portions of the watershed or inland portions of the coastal area.

Alteration of the natural balance on a single site may only have a small impact. But the cumulative impact of many individual sites or of large-scale developments, as is the rule more than the exception, can be massive. This is amply illustrated by the flash flood in Kansas City in 1977. Due to an unusually heavy thunderstorm, the rapid accumulation of runoff in a highly developed urban area created a six-feet-high wall of water in an otherwise dry creek bed. The result was over $30 million in damages and 24 lives lost.

Development at any place in the watershed can reduce the permeability of the soil, thus increasing runoff and flood levels. This increase in flood levels can then endanger properties that may have previously been above the base flood elevation.



Development Pressures

Human occupation of flood-prone areas brings with it inevitable losses of life and property and the disruption of commerce and services. Despite a long history of such losses, we continue to build and rebuild in hazardous locations. Ideally, this should not happen; however, the forces of development are as inevitable as the storms that produce flooding in the first place. In many cases people are unaware of the hazards of a given site or the effects of development on flooding at other sites. In yet other cases the risks are known, but locational advantages seem to override the hazard. Or the existing infrastructure in a flood-prone area is considered too enormous a capital investment to abandon. Too often, the speculative pressures of development override common sense.

Flooding is a normal occurrence, with the degree of

inundation influenced first by precipitation or storms, and then by such natural characteristics as topography, soil porosity, drainage, vegetation, and beach composition. Development in flood-prone areas often alters these natural features and can increase flood levels, chiefly by increasing the rate of water runoff.

To minimize adverse impacts, development should be prohibited or minimized in the most hazardous areas and carefully monitored to avoid undesirable effects in others. The design of the built environment should be carried out with complete knowledge of flooding characteristics and with conscious concern for maintaining the balance of environmental features.

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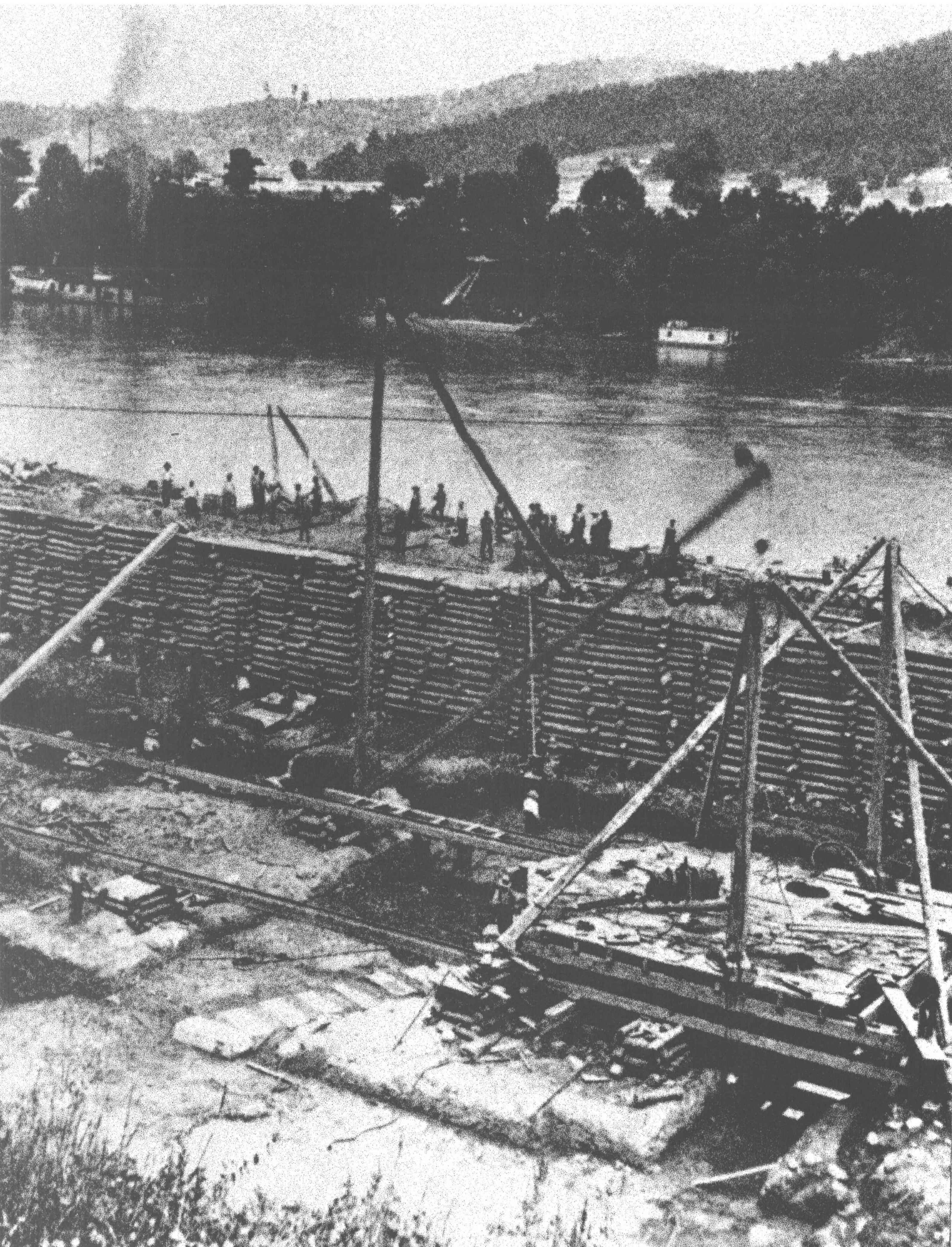
Development in flood-prone areas frequently results in damage to buildings. The house at far left has been swept completely off its foundations by the force of a riverine flood. The house above has suffered similarly from coastal flood water. Shown at left-center is the inundation of a small town's entire central business district.



Chapter 3

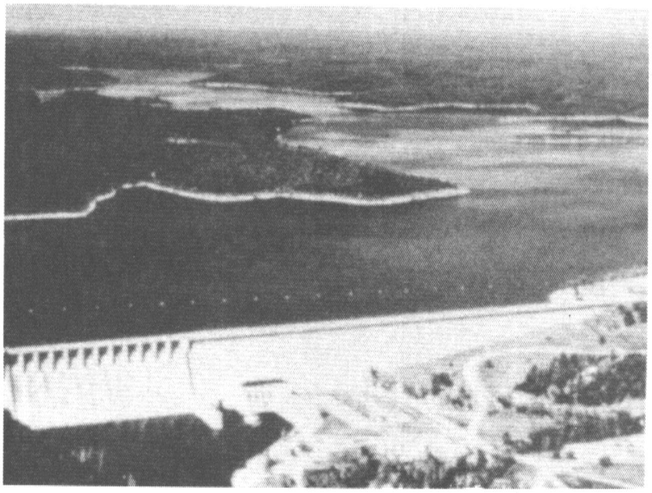
Policies, Programs, & Strategies for Flood Damage Reduction

Through time, the natural riverine and coastal systems have experienced increasing pressures from a rising population, the shift from an agrarian to an industrial society, and the limited amount of land close to water. Growing technological ability provided the means to translate these pressures into expanded development in flood-prone areas—even in the face of repeated disasters that showed that flooding cannot be controlled. The resultant cycle of destruction and rebuilding has been made more palatable for some due to the benefits of locating near the water. At the same time, there have been constant efforts to reduce the risk of flooding, with the federal government taking the initiative.

Evolution of Flood Policy

Early measures to reduce flood hazards in this country—most commonly, dikes and levees, seasonal evacuation, and buildings on stilts—were limited, and were usually the result of private or local initiatives. Since the 1920's, however, there has been a surge in technological advances and an active interest by the federal government.

In 1928, after a devastating flood of the lower Mississippi Valley, Congress passed the Lower Mississippi River Flood Control Act to provide federal funds for flood control in that region. The subsequent Flood Control Act of 1936 enlarged the scope of Congressional interest by declaring that flood damage was a national problem and should be addressed with federal funds. This legislation, which shaped policy for 30 years and remains an important influence on it, directed federal efforts towards preventing floods by *controlling* the flow of water in the nation's major river systems. This policy was implemented by the construction of structural modifications such as dams, levees and channel improvements.



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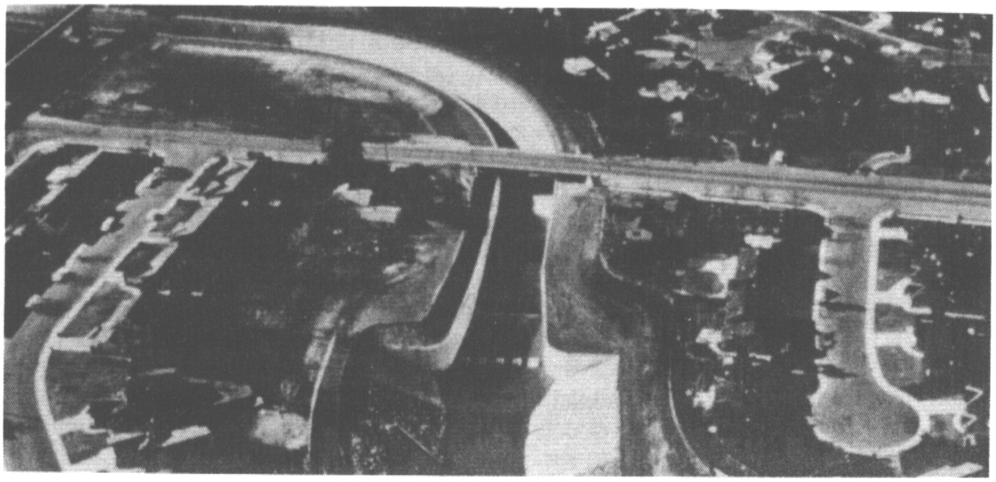

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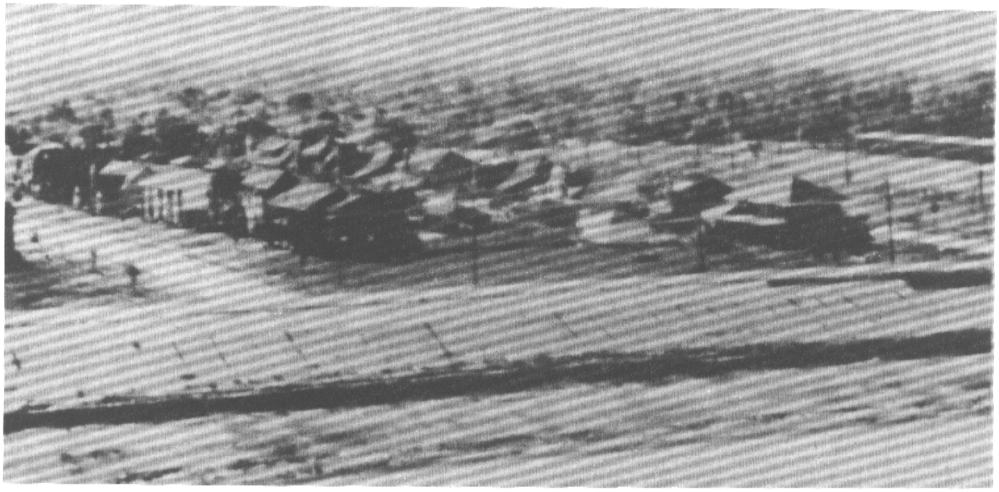
Flood control projects such as the dam and reservoir above and the channelization project at left have been constructed in an attempt to reduce flood damage by controlling stream flow.

Levee construction in 1890, U.S. Army Corps of Engineers



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Levees are constructed to protect developed areas from flooding.

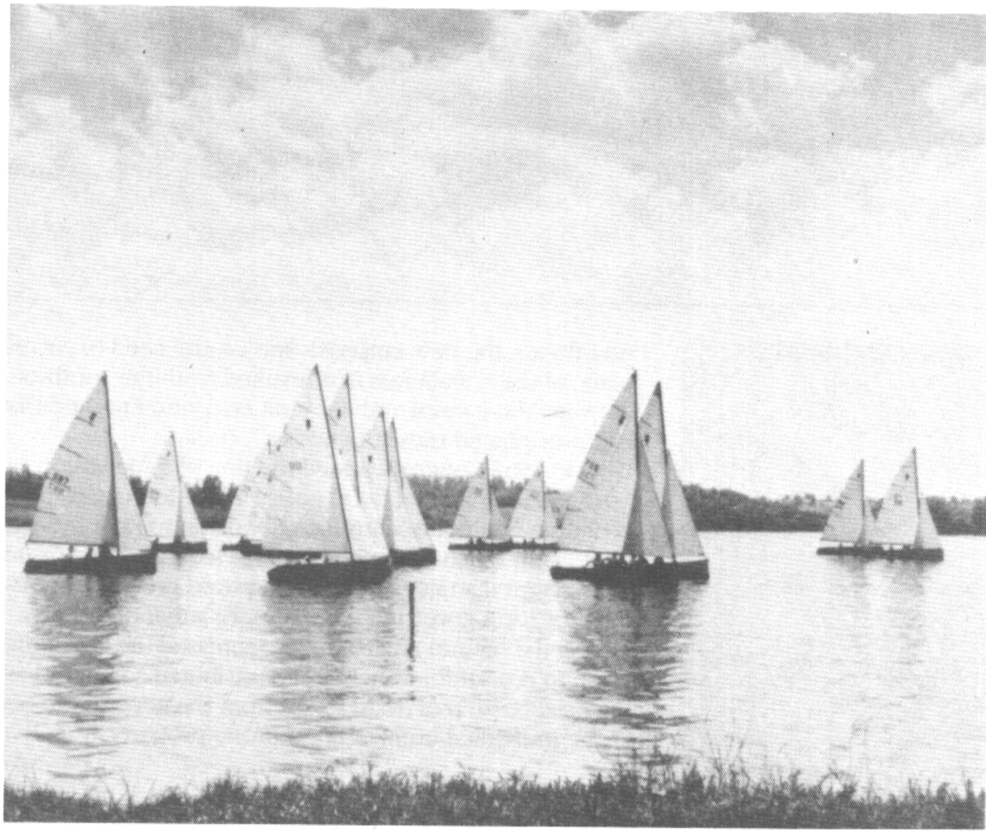
Between 1936 and 1965 the government constructed 260 reservoirs, 6,000 miles of levees, and 8,000 miles of channel improvements, with an expenditure of over $7 billion. This massive effort did provide protection for many previously vulnerable areas and had other positive benefits, yet did not reduce the expenditure for flood damages: In 1953 flood relief and rehabilitation required a federal expenditure of $53 million; by 1965 this figure had jumped to $237 million.

Policy Results

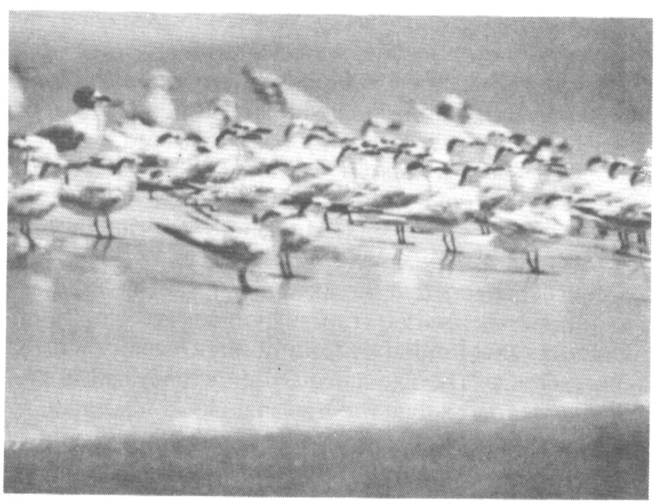
Federal programs to provide structural flood control projects have had numerous benefits. Increased control of river flow has often resulted in less inundation of major floodplains during times of heavy runoff. In effect, this has expanded the usable area of the floodplains, opening the way for increased economic opportunities in those areas. In addition, there have been significant increases in recreation opportunities at the many reservoirs and, in some cases, an increase in wildlife conservation habitats.

However, flood losses have climbed despite the structural program. It was found that preventive measures were not synonymous with elimination of flooding and that new development was frequently located in vulnerable locations. Thus when the limits of structural controls were exceeded and flooding did occur, damage resulted on a larger scale.

This was exacerbated by a simultaneous trend of rapid urban expansion. The growth of cities, already located in flood-prone areas, created development pressures for all available land. This pressure extended onto floodplains, which were perceived to be safe because of the structural flood control programs. These combined pressures caused insufficient attention to be directed at

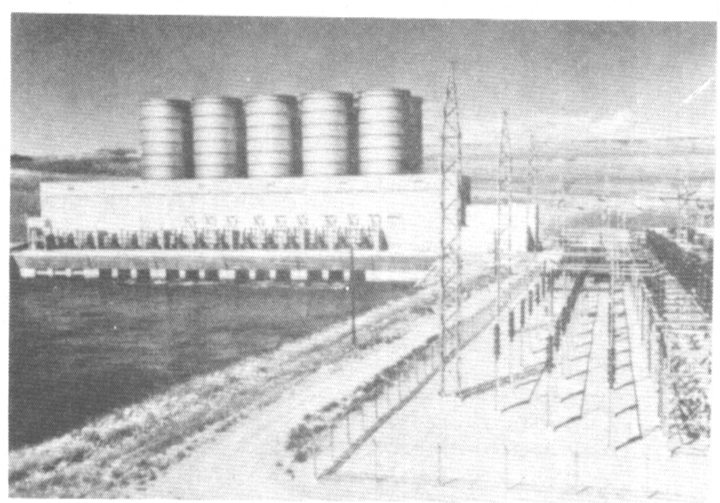


Heritage Conservation and Recreation Service



National Park Service

Flood control projects can have numerous benefits. They often generate hydroelectric power and create recreation and conservation habitats.



U.S. Army Corps of Engineers

maintaining equilibrium in the total watershed system.

The federal program for structural control of flooding also failed to provide an effective deterrent to coastal flooding. The programs were aimed predominantly at the riverine environment, largely because little hurricane activity occurred during the period in which early flood-related legislation was passed. Consequently, little Congressional attention was focused on the unique problems of the coastal environment.

New Focus of Federal Policy

In the middle 1960's there was a reassessment of national policy and the beginning of a shift to a more comprehensive approach to flooding. Paramount was the recognition that structural works needed to be complemented by nonstructural measures. Rather than trying solely to pre-